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OVERSEAS VISIT REPORT MARCH - APRIL 1988

A SCIENTIFIC UPDATE ON HF COMMUNICATIONS RESEARCH

K.J.W. Lynn

SUMMARY

This report covers a visit by Dr. K.J.W.Lynn of the Electronics Research Laboratory from 27 Mar to 26 Apr 1988 to the USA, UK, and the People's Republic of China. The purpose of the visit was to obtain a scientific and technical update on HF Communications Techniques.

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1 INTRODUCTION

This report covers a visit by Dr. K.J.W. Lynn of the Radiowave Propagation Group, Electronics Research Laboratory to the USA, UK and the People's Republic of China during the period 27 March to 26 April 1988.

The trip was for purposes of scientific and technical update. Specific aims were:

(a) to visit USA and UK research establishments active in the applications of propagation via the ionosphere to the enhancement of HF military communications,

(b) the application of backscatter sounding to the frequency management of HF communications.

(c) to attend the IEE HF Radio Systems and Techniques Conference held in London over the period 11 to 14 April,

(d) to attend the International Symposium on Radio Propagation in Beijing over the period 18 to 21 April.

The establishments visited were SRI International, San Fransisco; Naval Oceans Systems Centre, San Diego; Naval Research Laboratory, Washington; Rutherford-Appleton Laboratory, Chilton; University of Leicester, Leicester and Plessey Military Communications, Havant.

2. SRI INTERNATIONAL

Initial discussions were made with Mrs Georgellen Smith who provided the following background. SRI International is a private "think tank" and research company with a staff of more than 3000. The company depends heavily on US and foreign government contracts with particular emphasis on third world countries for whom it can supply expertise otherwise unavailable. The currently most profitable research areas are in the fields of agriculture, biology and economics.

SRI International has maintained an active interest in HF radio propagation since its founding although its most active period in this field seems to have been in the 1960's when it was a world leader in the development of backscatter sounding and OTH radar. The section dealing with HF communications recently closed as the company has consistently failed to win US government contracts in this field against competition from the Mitre Corporation. Work continues in the area of OTH radar.

The main topic discussed at SRI International was backscatter sounding. In particular I tried to determine whether any conclusions had been reached as to the effectiveness of this technique in providing frequency management to a one-way communication system such as NAVCOMMSTA.

Independent discussions were held with Mrs Smith, Dr George Carpenter and Dr Tom Croft. Of these three, Smith and Carpenter were optimistic about the effectiveness of this technique and Croft was pessimistic. I was not immediately able to resolve the conflict of opinions received (based on the same experimental data) until subsequent reading of the material obtained (ref.1) revealed the following facts.

The tests were made in the 1960's by R.B. Fenwick and associates using Voice of America (VOA) transmitters and antennas with reception areas in South East Asia, Europe and South America. Backscatter sounding was carried out using VOA broadbeam antennas for both transmission and reception. The tests in South East Asia were over one-hop paths of approximately 1500 - 2200 km with the sounding being done from the Philippines and signal monitoring mainly at Bangkok. Estimates of skip distance by backscatter sounding proved accurate to 50 - 100 km during these tests, but detailed correlation between the received signal and the backscatter estimate of signal strength proved poor. Good skip distance definition was also obtained over a 1500 km path between Munich and Istanbul. The poor correlation of backscatter with observed signal strength was attributed to the spatial averaging of the broad-beam antennas used. A narrow-beam receive antenna was recommended for any further tests.

Tests were also carried out over three-hop paths from the USA to Europe and South America at distances in the range 6500 - 7000 km. Good results were obtained over the path to Brazil where the backscatter sounder correctly identified an area of low received signal strength with a maximum occurring at longer ranges.
On the other hand, backscatter observations of skip distances over a path to Munich were consistently out in range by some 400 - 1000 km. The suggestion was that the simple ionospheric model used to convert time-of-flight to ground range was inadequate for this path.

In considering the relevance of these results to NAVCOMMSTA it is clear that the equipment used for sounding and verification was inferior to that envisaged for operation in Australia. Despite this, good results were obtained at ranges of 1500 km (consistent with our own observations using the Jindalee backscatter sounder over a 1200 km path). For NAVCOMMSTA I had conceived of first hop measurements only as being effective with a question mark on the second hop. The fact that some useful results were obtained by SRI over a three-hop path was more than I would have expected. Thus Croft's pessimism seems to have been based on having unrealistic expectations in the first place since it was these longer path results which he regarded as failures.

The discussions with SRI International indicate that the backscatter test program proposed by DNCD is justified by the inadequacy of previous testing in this field. The SRI International results highlight the need for the determination of ionospheric tilts in the area of operational interest and the importance of sophisticated skywave modelling to assist in converting the observed time delay in signal returns to ground position, particularly beyond first hop range. SRI indicated that even a good skywave modelling computer program such as IONCAP is inadequate for multihop calculations because it does not take ionospheric tilts into account. A program called AMBCOM was recommended. A copy of this program is available at DSTO Salisbury and is currently being used in Jindalee studies.

VOA has the same problem as NAVCOMMSTA of wishing to provide RTFM for transmissions beamed to areas where confirmation of reception cannot be obtained. SRI International has recently been tasked by VOA to re-examine the use of backscatter sounding in the light of technological improvements since the tests of the 1960's.

3. NAVAL OCEAN SYSTEMS CENTRE

The Naval Ocean Systems Centre (NOSC) at San Diego is tasked with meeting the more applied research requirements of the US Navy as against the Naval Research Laboratory (NRL) in Washington where research of a more fundamental nature is carried out. While this is the principle, in practice NOSC has a much better theoretical capability than NRL in some aspects of electromagnetic propagation. AT HF, the two laboratories appear to operate at the same level with little mutual cooperation. Discussions on HF matters were at NOSC with Mr David Sailors, Mr Bob Rose and Dr Adolph Paul. Brief discussions on VLF and VHF tropospheric ducting were held with Dr Richard Pappert and Mr Karl Kuegel.

3.1 Prophet

The current status of the HF Skywave prediction program PROPHET developed at NOSC by Sailors and Rose was investigated. RWP Group, DSTO Salisbury is the Australian custodian of this program which is in use with the Australian services.

Further basic development of PROPHET has stopped following a recent budget cut in US military funding. As a consequence, the version of PROPHET currently held in Australia will not be upgraded in the foreseeable future despite some upgrade modules having been developed by NOSC.

Contracts relating to PROPHET are still being worked on at NOSC for users such as the US Coast Guard who have paid to have changes to PROPHET displays to suit their specific requirements. A contract let by NOSC to develop on improved field strength model is still in operation, the current model being regarded as inadequate.

Further improvements to PROPHET envisaged by Sailors, should funds again become available, included the use of a T index equivalent (based on the Australian IPS algorithm) for use in updating PROPHET in near-real-time applications. The current method of using an artificial sunspot number is not regarded as more than a stop-gap measure. A better Lowest Useable Frequency (LOF) model was also needed. However, both this and the improved field strength model require experimental data for development and validation. Such data continues to be hard to obtain. Thought has been given to extending the applications of PROPHET by including a prediction model for scintillation occurrence in satellite communications and a model for the availability of meteor burst communications. Studies have been completed to provide auroral zone absorption (ref.2) and Sudden Ionospheric Disturbance models (ref.3).

I mentioned that RWP Group was considering upgrading PROPHET by replacing the MINIMUF skywave prediction model with one developed by the Australian Ionospheric Prediction Services for their Stand-Alone Prediction System (SAPS). Mr Sailors saw no technical problem in doing this and expressed no concern in our making such a change for Service use in Australia.

NOSC reports relating to the development of MINIMUF were obtained (ref.2,3,4,5,6,7,8,9). They show the initial concept of PROPHET was to use prestored tables of HF predictions for specific paths as developed for field use by a large computer. MINIMUF-3 was subsequently devised

as a means of producing generalised predictions on the very small capacity microprocessor-based computers becoming available in the late 1970's. The algorithm developed was adjusted to give an optimum fit to an oblique sounding data base covering paths in the range 800-8000 km. The algorithm calculates a vertical incidence value of foF2 and converts this to an oblique path value using an M factor derived using a parabolic layer model of the ionosphere of fixed height (peak electron density at 290 km) with correlation factors for seasonal and equatorial effects (ref.4).

MINIMUF was upgraded to version 3.5 in 1978 by allowing path calculation beyond 8000 km and improving the geometric path algorithm (ref.5). Detailed testing of MINIMUF 3.5 using a larger data base was completed in 1981 (ref.6). A noise model was developed in 1982 (ref.7). The need for further improvements was identified in these tests in order to cover a wide range of operating conditions. This resulted in MINIMUF 85 published in 1986 (ref.8). In the development of MINIMUF 85 comparisons were made with vertical sounder data as well as oblique, the sunspot dependence was improved, the M factor algorithm modified to include a greater range of factors and a special foF2 model added for use in polar regions. In these developments, no improvement in the accuracy of MINIMUF occurred against the original version, but the range of conditions to which the model applied was extended. A new accuracy assessment was completed in 1986 (ref.90).

MINIMUF 85 occupies 291 lines of BASIC code as against 99 lines in the original MINIMUF 3. The MINIMUF module in PROPHET is currently only a very small part of the total program, the original requirement for a fast compact code having been made redundant by the rapid growth in the speed and memory available to personal computers.

NOSC appears understandably reluctant to abandon MINIMUF because of the major effort put into conceiving, developing and testing this program over a ten year period. However some of the more accurate main frame programmes it was meant to approximate will now run on personal computers, so that the original requirement is no longer pressing. The MINIMUF algorithm will continue to have applications where speed and compactness is at a premium.

3.2 Ionospheric variations

Rather surprisingly, the pure research program on HF propagation was untouched by budget cuts and continues in the capable hands of Dr Adolph Paul. Dr Adolph Paul gave me a recent report (ref.10) which investigated how often ionograms need to be taken to define the time variability of the ionosphere with accuracy and the best ionospheric parameter to measure that variability. He finds that oscillations in the F2 region have a typical period of around 20 minutes and are nearly always present.

These oscillations can be seen as a movement in vertical reflection height at any frequency within an ionogram indicating the whole bulk of the ionosphere is effected. The oscillations appear less distinctly as a movement in the F layer critical frequency. These results indicate that ionograms need to be taken at about five-minute intervals to track movements. He finds that the rate of change of F region parameters and the localised tilts engendered are comparable with those associated with the geographically larger changes occurring at sunrise and sunset.

Paul recommends the use of the M(3000) parameter for the detection of F region movements since this parameter responds to both height and critical frequency changes and is measured from that part of the ionogram most likely to be well defined.

Paul is attempting to get a variation of the Dynasonde research ionosonde (developed at NOAA) in operation to continue his investigations of ionospheric movement. The Dynasonde provides Doppler and angle of arrival measurements as well as the more usual ionospheric parameters.

3.3 Waveguide modelling

I talked briefly with Dr Richard Pappert who has been involved in the application of waveguide theory to both VLF propagation and VHF propagation in tropospheric ducts. A report on the NOSC tropospheric ducting computer model called XWVG was obtained (ref.11). XWVG is a successor to an earlier NOSC program called DUCT which has seen much use. XWVG assumes that the refractivity profile can be modeled by three linear segments. A new model called MLAYER is about to be released which will generalise the refractivity profile to any number of segments.

A report was also obtained from Karl Kuegel which presents much of the VLF diurnal phase and amplitude variations collected in the NOSC experimental program carried out for the US Coast Guard OMEGA navigation office (ref.12).

4. NAVAL RESEARCH LABORATORY

Talks were held at NRL in Washington with Dr John Goodman, head of the Ionospheric Effects Branch. Goodman noted that while HF communications research for the US Army was still proceeding at Fort Monmouth, New Jersey and at NOSC and NRL for the US Navy, in his opinion the bulk of the funding and the most innovative research in ionospheric physics and HF propagation was going to US Air Force laboratories.

Currently only two research staff members apart from himself were engaged on HF work in his group; namely, Dr Mark Daehler and Dr Mike Reilly. Of these, Daehler appeared to be in charge of the ionosonde and experimental aspects while Reilly concentrated on the more theoretical aspects. The main thrust of current HF has been directed towards the use of oblique sounders for RTFM, the extrapolation of such data forward in time by updating HF prediction models and extrapolating the data in space to cover regions at some distance from the sounder reflection point.

As with others wishing to use PC based HF prediction programmes, Goodman has made the development of an oblique sounder data base a long term preoccupation both to test such programmes and also to allow the development of his own ideas on RTFM strategy. The data held includes high and low sunspot numbers but mainly covers the US and Europe. He is willing to supply such data to others and would like to receive data in return.

Goodman is particularly keen on the concept of providing RTFM for NATO in Central Europe by setting up oblique sounders in a triangle so that their reflection points (control points for RTFM) form an inner triangle of side no greater than 425 km. The length of the oblique paths should not exceed 1875 km to ensure single hop propagation on all skywave modes. This concept essentially relies on the availability of NATO countries exterior to the postulated main battle zone and while initially feasible in Europe, would be less relevant in the area exterior to Australia of defence interest to us. Recent work by Goodman's group was summarised in a paper reported in the London IEE conference (ref.13).

Measurements made by Daehler and Reilly indicate that an HF prediction program such as PROPHET should be updated by external sounding once an hour in order to achieve a halving of the error associated with the prediction program. Their measurements also indicate that after seven hours, the updated values are, on average, no better than the standard model predictions. It would be interesting to repeat this work in Australia particularly as it would allow a separation of disturbed and non-disturbed conditions which could have quite different characteristics.

Reilly has recently published a paper describing the computation of the ionospheric electron density profile at an oblique sounder reflection point. This method requires the conversion of the oblique to an effective vertical ionogram.

He is currently working on a program which will go directly from the oblique ionogram to the electron density profile. Such a program would greatly increase the value of oblique sounding in characterising the distant ionosphere.

5. RUTHERFORD - APPLETON LABORATORY

Discussions were held with Mr Peter Bradley, head of the HF Radio Propagation Group within the Rutherford - Appleton Laboratory. The Rutherford - Appleton is something of a showcase for British science with emphasis on nuclear and particle physics, large particle accelerators, astrophysics, lasers and other high profile areas considered to be internationally prestigious. In recent years, Bradley's group has carried out contracts or supervised contracts to universities and industry for bodies such as the Ministry of Defence, GCHQ and the BBC.

Bradley currently chairs a CCIR committee tasked with examining HF skywave prediction for personal computers with a view to recommending a CCIR standard. The current list of such programmes known to Bradley stands at 22 and includes the Australian IPS program SAPS developed for the RAN. Bradley is going to try for MICROP2 as the CCIR recommendation on the basis that it is one with which he is familiar. He pointed out that most programmes are inadequately documented, particularly as regards to testing, and of doubtful availability. There was no way that his CCIR committee could adequately test these programmes to provide a real comparison of accuracy.

At the London meeting a few days later I asked Dr David Cole, head of the Australian Ionospheric Physics Service for his reaction to Bradley's comments. He replied that MICROP2 AND SAPS were both based on the same CCIR-recommended ionospheric data base so that both should give essentially the same answers apart from minor differences arising from the mathematical methods used in interpolating data. Apart from mavericks such as MIMIMUF where NOSC attempted to build its own data base, any program using the CCIR data base should provide similar answers, although

discrepancies may arise if differing algorithms are used in the conversion to oblique parameters and in the calculation of field strength.

As with Sailors and Goodman, Bradley was keen to see the development of an oblique sounder data base for the testing of models and would like to publicise the availability of any Australian data which could be supplied. The calculation of HF field strength is seen as a continuing problem and CCIR has recommended a new program of signal strength measurements world wide. Because few ionosondes can provide absolute field strength data, the installation of nine dedicated transmitters has been proposed, cycling through several discrete frequencies. A contract has been given to Prof. Darnell (University of Hull) to produce a prototype transmitter and omni-directional antenna of known characteristics. The receiver is to be kept simple and use a short vertical whip.

The Rutherford - Appleton Laboratory continues to operate ionosondes at Slough, South Uist and the Falklands Islands. The US Army has recently let a contract to obtain better ionospheric data over Europe. Bradley was approached by both the principal tenderers, ALCOA and Lovell University. The contract was won by ALCOA (in Bradley's opinion, the least competent tenderer) and he is currently being paid to supply vertical and oblique sounder data from Slough.

The British OTH radar development was also discussed. Bradley was pessimistic about its prospects for two reasons. The first is that it will look north into the auroral zone which is ionospherically the worst part of the world to operate an OTH radar. The second is that the construction and development is being undertaken by too many organisations, in his opinion, without an adequate system of supervision by a central authority with the necessary expertise.

Discussions were also held with a theoretician working on thermospheric wind modelling. There are two major groups competing in this arena, one in the USA and one in the UK (University College London combined with Sheffield University). The models developed give promise of predicting up to half the day-to-day variability of the ionosphere in terms of varying energy inputs at the auroral zones. These inputs modulate the upper atmospheric wind systems which re-distribute F region ionisation (a particularly important mechanism at night). He suggested that the other half of the variability may lie with meteorological conditions below the ionosphere.

6. UNIVERSITY OF LEICESTER

Discussions were held with Professor Tudor Jones of the Physics Department. The main purpose here was to ascertain the nature of their current work on the resolution of skywave modal components using multiple antenna arrays.

The main ionospheric work in the Department is directed towards the auroral zone which is of most defence interest to the UK and in which there are large European ionospheric installations (eg EISCAT) accessible to the UK. Work is still being done on HF direction finding with large aperture antenna arrays.

Recent theses in this area indicate a continuing pre-occupation with the spatial effects of interfering skywave modes rather than their separation in the time domain by Doppler spectral analysis. I left feeling the approach taken by RWP Group in this field is not simply duplicating work previously done in the UK.

7. IEE CONFERENCE

The Fourth International Conference on HF Radio Systems and Techniques was held in the headquarters of the Institute of Electrical Engineers, Savoy Place, London over the period 11 to 14 April. The conference was well attended with a large international component. Papers were delivered in eight subtopics with two sessions often operating in parallel (ref.13).

Only one British company was usually represented in any given area suggesting the distribution of current development contracts. Thus Plessey delivered papers on HF communication systems, Marconi on ground wave HF radar and Racal on wide aperture HF DF arrays.

Brief summaries of the various sessions are attempted below:

7.1 System design, control and networking

This session contained the largest number of papers with four from universities, ten from commerce and eight from government organisations. This breakdown was indicative of the attendees affiliation as a whole. Most papers in this session bore on the problem of implementing an adequate control of HF communications, including automatic linking and operation. Nearly all systems described included real-time frequency management and channel evaluation functions.

As might be expected from their proximity to the venue, Plessey gave a strong showing in terms of papers delivered and in the overall coverage of problems associated with the control of HF networks. A good paper was provided by Plessey Pacific Defence Systems based on their work to meet Australian Army requirements.

Conversation with a Plessey representative suggested that RTFM and channel evaluation has to be designed into a total HF communications system and that an add-on pilot tone sounder such as developed by Andrew Antennas (CQS) was an obsolete approach. A representative of Andrew Antennas on the other hand said that the channel evaluation techniques described in the session were years behind the methods employed in their CQS sounder. In my opinion both speakers were correct. New HF networks should employ integral RTFM and channel evaluation. Unfortunately few commercial companies have yet to develop the range of expertise to encompass all that is involved in such a system. Consequently when looked at in isolation, most of the embedded channel evaluation techniques described at the conference seemed crude, rarely getting above the identification of free channels or an S/N measurement.

However, it was also evident that in large multi-user systems, the immediate criteria is not to obtain an optimum channel so much as an available channel since an optimum channel would probably already be occupied. The inference is that only systems with a small number of users or operating over fixed links could afford the luxury of optimising throughput by more sophisticated means. In this context, the CQS type of sounder may be more applicable, particularly as it can be added to existing equipment.

Data rates in the systems described were very low with nothing over 300 bits/s being mentioned, except in a system developed by TADIRAN where data rates up to 2400 bits/s were employed.

The only two papers discussing the use of oblique ionosondes for RTFM were directed towards military applications. One paper by Dr John Goodman described the European sounder approach discussed in paragraph 4. The other papers described an actual system developed by TADIRAN incorporating oblique ionosondes for RTFM over a system of strategic military links. Here the ionosonde outputs were digitised and processed by computer agorithms to derive frequency availability and a quality factor. The final frequency recommendations were made at a central HQ on the basis of the information provided.

This session concluded with two papers on meteor burst communications as developed at the Royal Aircraft Establishment (RAE). The BLOSSOM system was designed to provide secure air-to-ground and ground-to-air communications at frequencies between 36 and 71 MHz. Data was sent at varying rates up to 9600 bits/s but average throughput on an hourly basis was around 15 bits/s.

7.2 Antennas

Two papers described methods of modelling mutual coupling effects between antennas mounted on ships. Two papers described wide-band HF antennas suitable for skywave reception. Both antennas used loading within the wire structure to give wide band operation. A paper by C&S Antennas Ltd (UK) described a vertical incidence transportable HF antenna somewhat similar to that supplied with MEDPORT.

A small horizontal loop antenna developed by SRI International for skywave reception was described. The principles of operation could well apply to a vehicle mounted antenna. Other papers dealt with problems associated with large antenna arrays.

7.3 Noise, Interference and modelling

A three-paper session with two papers developing models of noise (mostly man-made) and channel occupancy in the European environment. The third paper was from the USA and dealt with a wide band HF noise and interference model applicable to spread spectrum communications via skywave paths over a bandwidth of 1 MHz.

7.4 Propagation

Although labelled propagation, this four-paper grouping dealt mainly with the problem of HF skywave prediction. Of these, two papers described the use of an ionosonde, one vertical in a short range role, the other the use of oblique sounding to frequency manage long range diplomatic links. The latter paper found that updating an foF2 algorithm taken from MINIMUF for the month ahead, based on sounder data taken over the previous month, gave better predictions than using CCIR, MINIMUF or IONCAP on their own. The paper proposed rotating an ionosonde transmitter amongst ten diplomatic posts. This seemed a rather improbable solution.

7.5 RF equipment and techniques

A miscellany of topics in this session covered low distortion RF components, including HF transmitters, digital signal processing based HF receivers, skywave direction finding and error correction codes. A paper by RACAL gave a very illuminating technique for processing phase measurements from a circular antenna array by

means of the fourier transform, giving directions of signal arrival in both azimuth and elevation as well as a measure of wavefront distortion.

7.6 HF Radar

Four papers dealt with HF ground-wave radar and associated problems. The UK seems to be getting something of a lead in this field. Two of the papers were by Marconi Radar Systems describing a test radar looking across the North Sea to the Netherlands. The other two papers came from the University of Birmingham on related research matters.

The remaining six papers in this session dealt with HF skywave OTH radar or backscatter sounders. Two of the papers were delivered on the Jindalee OTH radar and one on a system in the People's Republic of China. The French backscatter displays currently available seem rather crude (similar to Jindalee stage A) but they have made good progress in developing 360 degree coverage antennas and in some theoretical aspects of processing the backscatter information. One paper dealt with correcting the sea backscatter return for ionospheric Doppler movement while another gave a practical method currently employed to solve the inversion problem of defining ionospheric characteristics (including tilts) over large geographic areas from backscatter observations. The final paper, co-authored by Dr Louis Bertel (who worked on Jindalee backscatter data during a recent visit to IPS), described the design of a 360 degree coverage circular array of colocated transmit and receive antennas being built for backscatter sounding on an island off the French coast.

7.7 Signal design and processing

Three papers dealt with digital voice encoding for HF links, three with experimental modulation techniques and the final seven with HF modem development for high speed digital data transmission and ionospheric channel simulations developed for testing such modems. Most of the modem-related work dealt with various schemes for dealing with the multipath skywave channel when using serial tone transmissions. It continues to be disturbing that these investigations use models of HF path fading which appear to be based on statistical algorithms rather than physical models as do the ionospheric simulators being developed and used.

An interesting paper by Pennington dealt with the effect of man-made signal interference on the performance of actual serial and parallel tone modems. He concluded that the serial tone modem evaluated was significantly more resistant to interference than the parallel tone modem tested, which although not stated in the paper, appear to have been the Fredericks HSM-1 and the Rockwell Collins TE 233S.

8. PLESSEY MILITARY COMMUNICATIONS

A half day visit was made, at their invitation, to Plessey Military Communications Ltd situated at Southleigh some miles north of Portsmouth. A Plessey Adaptive Automatic HF radio system was explained and shown to me. This system was developed to meet a UK Ministry of Defence requirement for a Home Defence Radio System (HRDS). The development behind it was the subject of several papers at the IEE conference.

HDRS is conceived as an emergency HF communications network which could provide a basic communications facility throughout the country following a nuclear attack. To meet these requirements, each system is capable of originating and receiving traffic and contains the same embedded software control centre or frequency management station in a system of from 2 to 100 users. The frequency management is transparent to the users and involves the use of a skywave prediction model, regular sounding between the control and FMS sites and a knowledge of which channels are currently operating successfully. Data rates are varied automatically to suit conditions with 300 baud being the maximum. Typical daily throughput during testing averaged about 60 baud.

The HDRS shelter was about the same size as a MEDPORT shelter but considerably less crowded. The shelter was pulled as a trailer (eg by a Land Rover) rather than being mounted on a truck. The antenna was again similar to MEDPORT however the lower-speed modem required a lower S/N for operation with a consequent reduction in transmit power to 250 W.

9. ISRP CONFERENCE

The International Symposium on Radio Propagation was co-sponsored by the Chinese Institute of Electronics and held in a hotel some miles out of Beijing (ref.14).

Session headings were:

(i) Wave propagation in random media

(ii) LF, VLF and ELF propagation

(iii) Ionospheric physics

(iv) Wave propagation theory

(v) Millimetre wave propagation

(vi) Inverse scattering

(vii) Whistlers

(viii) Electromagnetic scattering

(ix) VHF propagation

(x) Radio sounding of the Earth's environment

(xi) Line-of-sight propagation

Parallel sessions were in operation and I attended the ionospheric physics sessions in preference to others. No major discoveries were reported. The chief value of the meeting lay in the range of ideas covered and the overview of where research effort is going. Because of the location many papers dealt with ionospheric parameters measured at Australian longitudes and were thus of greater interest than is often the case.

Specific ideas of relevance to the work of RWP Group included recent studies on the nature of Spread F (in which Australian university scientists are making a significant contribution). A Chinese paper confirmed previous research indications that Spread F conditions at night follow an unusually rapid rise in F region height after sunset. Spread F is perhaps the most destructive ionospheric condition for HF communications, thus any reliable way of predicting its occurrence (even by a matter of hours) could be of significance where near-real-time frequency management techniques are being used. A rapid post-sunset height rise should be identifiable by automatic techniques using a digital vertical ionosonde thus giving an indication of expected propagation conditions later in the night.

Another Chinese paper of interest dealt with inversion methods for calculating the vertical velocity of ionospheric movements as a function of height from the doppler shift in ionosonde returns as a function of frequency. This again is a technique which will become available when RWP Group obtains a sounder which can produce doppler ionograms as well as the standard time-delay ionograms. Since relative doppler shifts from ionospheric reflections at differing heights produces the signal fading which degrades HF communications, a clearer understanding of the theory of doppler generation would be well worth pursuing.

All research papers by the Chinese were delivered in English, though often with some difficulty. The whole conference was free of any form of ideological content indicating the major political changes which have occurred in China since the Mao era. Chinese research appeared to be wide ranging though experimental equipment is still a little inadequate.

Concurrently with the ISRP conference, an International Beacon Satellite Symposium was being held. Several Australian university researchers made this their chief priority. I was only able to attend one afternoon session. This session and others reported to me suggested that the satellite beacon symposium was of greater interest in terms of ionospheric physics (as distinct from radio propagation). Beacon satellites allow the measurement of Total Electron Content (TEC) through cross sections of the ionosphere taken over large geographic areas. Such measurements form large scale pictures of ionospheric movement and density variations which are needed to understand the generation of the ionosphere and its response to external disturbance.

10. CONCLUDING REMARKS

The trip met the requirements of providing a close look at contemporary research in the several disciplines which bear on successful HF communications via the ionosphere. It also enabled comparisons to be made with the current research program of RWP Group. The RWP program in support of HF communications is based on;

(i) the development of an oblique sounder data base covering middle to equatorial latitudes in the area of Australian defence interest,

(ii) the understanding and development of contemporary HF skywave prediction models,

(iii) the use of ionospheric sounding (vertical/oblique/backscatter) as an aid to RTFM in a military environment,

(iv) the investigation of all time-varying mechanisms in the ionosphere which can effect HF channel quality and predictability as well as developing the means to resolve skywave modes.

It was interesting to discover that other propagation research groups charged with improving HF communications in a military environment had programmes similar to our own. However, in each case a shaping of the program to

meet specific needs had occurred. Low-latitude, equatorial and transequatorial propagation is receiving the most attention in our Australian program. In contrast, the USA, UK and NATO countries continue to put their major efforts into high latitude and auroral zone investigations. While lacking a strong theoretical component, the Australian program devised by RWP Group seems well balanced in terms of the desired goals. RWP Group is fortunate to retain access to a convenient, low-noise field site (St Kilda) along with the technical capabilities to design, build, modify and trial equipment. It was evident in both the USA and the UK that the move to external contracting to meet these requirements had resulted in a loss of initiative and control for the groups concerned when budget cuts occurred.

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This report covers a visit by Dr K.J.W. Lynn of the Electronics Research Laboratory from 27 Mar to 26 Apr 1988 to the USA, UK, and the People's Republic of China. The purpose of the visit was to obtain a scientific and technical update of HF Communications Techniques.

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